

SECTION 4

MEASURING AND REPORTING THE BIOLOGICAL INTEGRITY INDICATOR

4.1 Voluntary Pilot Biological Integrity Indicator

EPA is considering the addition of a new item to the 305(b) report, the biological integrity indicator. EPA has previously presented its concept of how this indicator would be assessed to States, both through its 305(b) Consistency Workgroup and in earlier drafts of these Guidelines, which were distributed to States for comment. Some States have supported the inclusion of biological integrity as a separate indicator while others have questioned its usefulness given that biological integrity is already considered in the assessment of aquatic life use support (ALUS). EPA believes that while much of the field work to assess biological integrity is already performed by States in their assessment of ALUS, a separate biological integrity indicator would add useful information to the 305(b) report (see box).

EPA is currently preparing to submit this indicator to the Office of Management and Budget (OMB) for approval under the Paperwork Reduction Act. As part of this process, States will be given a formal opportunity to comment to both EPA and OMB on the practical utility of this indicator, the additional burden associated with assessing it, and any other concerns they may have regarding its inclusion in the report. EPA is aware that some States are already preparing to

The Biological Integrity Indicator

The biological integrity indicator describes the condition of the biota and habitat in an ecosystem having minimal influence from human activities. The indicator measures the degree to which an ecosystem approaches this condition. Many States with biomonitoring programs can already measure some form of this indicator.

The traditional aquatic life use support (ALUS) assessment takes into account socioeconomic factors in State water quality standards. It can also be based on chemical data alone. The biological integrity indicator, on the other hand, must be based on biological and habitat monitoring and on comparison to reference conditions.

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assess biological integrity as part of their 1988 305(b) reports. EPA would welcome submission of these assessments and will use them in its ongoing evaluation of this item for possible inclusion in future 305(b) reports. States are not required to include assessments of biological integrity in their 1988 reports, although of course they should continue to consider biological and habitat monitoring in their assessment of ALUS.

For the benefit of those States that wish to submit with their 1988 reports the results of any biological integrity assessments they are already conducting, as well as to further inform subsequent comment on the inclusion of this indicator in future reports, EPA is providing these guidelines.

Biological integrity is “the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of a region” (Karr and Dudley, 1981; see also Angermeier and Karr, 1994). The State members of the 305(b) Consistency Workgroup asked that the biological integrity indicator be reported electronically rather than in their hard-copy 305(b) reports. This will avoid presenting assessments of aquatic life use support and biological integrity in the same State document, which might confuse the public. The voluntary pilot biological integrity indicator is thus included in the list of data elements in Section 6 of the main *Guidelines* volume.

The recommended approach for developing and reporting on the indicator is presented in Section 4.2 as three phases:

- C Develop reference conditions, the framework for making judgements of biological impairment
- C Design the monitoring network, including both historical sampling locations and new ones
- C Implement the monitoring program.

The information to develop a biological integrity indicator is described in detail below. This approach is compatible with biological and habitat assessment levels 3 and 4 in Tables 3-1 and 3-2 as well as the case studies for making ALUS determinations in Section 3. States may develop alternative approaches for measuring the biological integrity indicator, provided such approaches are compatible with levels 3 or 4 in Tables 3-1 and 3-2. Note that a good monitoring program should integrate biological monitoring with water column sampling; habitat,

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sediment and tissue monitoring; and other monitoring. Biosurvey monitoring should not be a separate program or done in a vacuum without other important types of monitoring.

The following outline of the three phases is **not** intended to be a complete description of the process for developing the biological integrity indicator. More complete technical guidance is available for many of the biological monitoring concepts and procedures described in this section. See *Biological Criteria: Technical Guidance for Streams and Rivers* (Gibson et al., 1996; EPA 822-B-96-001) and *Rapid Bioassessment Protocols for Use in Streams and Rivers* (Plafkin et al., 1989, EPA /440/4-89-001). For additional information, contact the EPA/OWOW Monitoring Branch at the number given on page ii.

The approach below has been applied to streams and rivers. Protocols for the measurement of biological integrity in lakes and estuaries are not fully developed. When these protocols are completed, reporting of biological integrity will expand into these waterbody types. In the interim, the States that have developed such protocols are encouraged to report biological integrity for as many waterbody types as possible.

4.2 Phases and Steps in Developing the Indicator

Although the steps in these phases are presented in a linear fashion below, the overall process is quite iterative, with some of the later steps providing information that allows testing of previous steps and refinement of the process.

Phase 1 - Develop Reference Conditions

The majority of the tools necessary for routine data analysis and site assessment are developed during this phase of the process. The approach presented here involves the use of reference sites; EPA recognizes that States may have other approaches for developing reference conditions.

a. Classify Natural Landscape and Waterbody Types Contained within Region of Interest.

- T** Partition the landscape on maps based on, for example, ecoregions, subcoregions, physiographic regions, watershed size, waterbody type, vegetation types, elevation, etc. Categories will serve as **preliminary** site classes.

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b. Select Reference Sites.

- T Identify multiple sites per site class that exhibit minimal physical or chemical degradation and meet specified reference site criteria.

c. Select Stressor Sites.

- T Identify multiple sites per site class with various degrees of known and documented physical and/or chemical degradation.

d. Sample Reference and Stressor Sites.

- T Using appropriate biological methods, sample sites.

e. Test Site Classification; Select and Calibrate Metrics (assumes a multimetric approach).

- T Calculate all potential metrics, indicate probable direction of change in presence of stressors
- T Exclude metrics that have no ecological meaning
- T Compare individual metric value ranges (from multiple reference sites) within and among preliminary site classes
 - If value ranges cannot be separated, combine 2 or more site classes and aggregate reference site data from combined classes
 - If metric values are highly variable within classes, examine alternative site classifications
 - Test final classification with analytical methods such as discriminant analysis, MANOVA, or ordination
- T Compare metric value ranges of reference sites vs. stressor sites within new site classes (i.e., test ability of each metric to discriminate between impaired and non-impaired)
 - Exclude metrics that fail to respond to stressors within a site class and lack discriminatory power (use statistical tests, if necessary).

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f. Develop Performance Characteristics of Calculated Values.

- T Need to know precision and uncertainty of index and metric estimates (preliminary estimates can be developed with single year of data).
- T Final determination requires repeated (replicate) samples, multiple year samples, and knowledge of site class variability.

g. Develop Metric Scoring Criteria.

- T After metrics have been selected, choose threshold for determining impairment (depending on direction of change in presence of stressor) as some percentile of reference value distribution. Divide remainder of range into successively lower scoring categories.

h. Determine Assessment (Index) Rating Scales

- T States use different approaches to continuous rating scales, typically using three, four and five categories. Currently, EPA is recommending a five-category scale such as excellent, good, fair, poor, and very poor (where *excellent* would be considered minimally impaired, that is, achieving biological integrity).

Phase 2 - Develop Monitoring Network Design
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a. Determine Types and Geographic Scale(s) of Questions to be Addressed (Site-Specific, Watershed-wide, or Region-wide)

- T Determine appropriate approach for site selection (random selection), special (targeted selection), or combined approach.

b. Determine Acceptable Data Quality Objectives (DQOs) for Assessment Results.

- T Base on *estimates of precision and uncertainty* of metrics and index (developed in Phase 1), as well as on availability of resources.

c. Select Sampling Sites.

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- T Select sampling sites using probability design, targeted design, or combined approach. Take advantage of historical sampling sites where feasible.

Phase 3 - Implement Monitoring Program

This is the routine monitoring program that will be performed regularly over specified time intervals, depending on the program. During Phases 1 and 2:

- " Metrics have been selected and calibrated; scoring criteria already developed
 - " Sampling locations have been selected based on monitoring objectives
 - " Field sampling and laboratory methods have been defined
 - " Index period has been defined
 - " Data management system has been defined and
 - " DQOs have been defined
- a. **Schedule field teams to complete sampling within index period.**
 - b. **Complete all sampling (as well as field taxonomy for fish) within defined time period; take duplicate samples (complete) at approximately 10% of sites.**
 - c. **Perform laboratory sorting and subsampling (benthos and periphyton, only).**
 - d. **Perform laboratory taxonomy (fish, where necessary; benthos; and periphyton) using a standard level of effort (i.e., consistent taxonomic levels for different organisms).**
 - e. **Using raw data from laboratory results, calculate selected *metrics* (selected during Phase I) for each sample.**
 - f. **Normalize metric values into unitless scores by comparison to *scoring criteria* (developed during Phase I).**
 - g. **Sum all metric scores for each sample.**

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- h. Compare summed metric total to *assessment rating scale* developed during Phase I.

T this step provides the site assessment of “excellent, very good, good, fair, or poor” (or other narrative rating terms)

- i. Compare precision and uncertainty values to the *DQOs* (developed in Phase I).

4.3 Reporting the Biological Integrity Indicator: Case Study

This section presents an example of metric calculation, index scoring, and judgement of impairment using actual data for a site. This is performed following the selection of reference sites and metrics, determination of final site classes, and development of reference conditions (i.e., scoring criteria). (Note: alternative methods are acceptable providing they are compatible with level 3 or 4 assessments in Tables 3-1 and 3-2). This example uses a benthic macroinvertebrate sample taken from a low gradient stream in the eastern United States and compares the laboratory results to the appropriate reference conditions. The text box on Page 4-7 presents definitions of the final metrics that were selected (Phase 1/step e above), the reference conditions used as the basis for scoring calculated metric values (Phase 1/step g above) and categories used for translating total bioassessment scores to narrative ratings (Phase 1/step h above).

Following sampling using appropriate methods for the stream type and region under study, the benthic macroinvertebrate sample is returned to the laboratory for sorting and taxonomic identification. An example of what results from laboratory processing of a single sample is shown in Table 4-1 and is a list of taxa, the number of individuals of each taxon, and their tolerance values and functional feeding group designations. This set of raw data represents Step 1 of the site assessment process.

Using the data produced in Table 4-1, the selected metrics are calculated, resulting in a set of metric values (Table 4-2). Each metric value is compared to the metric scoring criteria that were previously developed and normalized to scores, resulting in a list of metric scores (Table 4-2). For example, the site used for this example had a calculated value of 19.4 for the metric ‘% EPT (metric 3)’. Comparing that value to the scoring criteria, this site receives a ‘3’ for this metric. This comparison, or scoring, once done for all seven metrics, results in a list of metric values (Table 4-2) that can then be summed for a total bioassessment score. Comparing total bioassessment, or index, score to the narrative rating categories allows translation to a narrative assessment--**in this case, a Biological Integrity Indicator rating of “good” (Table 4-2). The State’s**

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electronic database (WBS or other) would then be updated to show this rating for the appropriate number of miles of this waterbody (e.g., 5 miles = "good").

The exact sampling methods, reference site selection criteria, metrics, scoring criteria, and narrative rating categories will vary according to the waterbody type and region, sampling index period, and sample handling procedures.

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Tools Developed During the Phase 1 Process that are Used During Bioassessment

Metric Definitions

1. Taxa Richness - the number of distinct taxa in the sample.
2. EPT Taxa - the number of distinct Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) taxa in the sample.
3. Percent EPT - the number of EPT individuals as a proportion of the total sample.
4. Percent Chironomidae - the number of chironomid individuals as a proportion of the total sample.
5. Number of Trichoptera Taxa - the number of distinct Trichoptera taxa in the sample.
6. Hilsenhoff Biotic Index - measures the abundance of tolerant and intolerant individuals in a sample by the following formula, where x_i is the number of individuals in the i th species, t_i is the tolerance value of the i th species, and n is the total number of species in the sample:

$$HBI' = \frac{\sum x_i t_i}{n}$$

7. Percent Collector-Filterers - the number of individuals that are members of the Functional Feeding Groups Collector or Filterer as a proportion of the total sample.

Reference Conditions

Metrics	Scoring Criteria		
	5	3	1
1. Total Taxa	\$23	22-12	11-1
2. EPT Taxa	\$8	7-4	3-0
3. %EPT	\$22.3	22.3-11.2	11.16-0
4. %Chironomidae	#33.6	33.6-67.3	> 67.3
5. No. Trichoptera Taxa	\$6	5-3	2-0
6. HBI	#5.5	5.5-7.8	> 7.8
7. %Collector-Filterers	\$57.2	57.2-28.1	28.1-12

Narrative Rating Categories

<u>Narrative Rating</u>	<u>Total Bioassessment Score</u>
very good	\$31
good	25-30
poor	18-24
very poor	< 18

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Table 4-1. An example of laboratory results from sorting and identification of a single benthic macroinvertebrate sample.

Taxon	No.	TV	FFG
DIPTERA	2	-	-
CHIRONOMIDAE	19	5	-
Tanypodinae	52	5	-
Orthoclaadiinae	7	5	-
Chironominae	1	5	-
<i>Tipula</i>	4	4	SHR
<i>Dixella</i>	1	1	COL
<i>Limnophila</i>	1	4	PRE
<i>Chrysops</i>	2	7	PRE
<i>Pseudolimnophila</i>	2	2	PRE
<i>Hexatoma</i>	1	3	PRE
<i>Simulium</i>	7	6	FIL
<i>Culicoides</i>	2	10	PRE
<i>Bezzia/Palpomyia</i>	2	6	PRE
<i>Mallochohelea</i>	5	-	-
<i>Phylocentropus</i>	1	5	FIL
<i>Hydatophylax</i>	4	2	SHR
<i>Pycnopsyche</i>	7	4	SHR
<i>Ptilostomis</i>	1	4	SHR
<i>Isonychia</i>	12	3	SHR
<i>Cheumatopsyche</i>	2	5	FIL
<i>Paranemoura</i>	7	2	SHR
<i>Leptophlebia</i>	3	4	SHR
<i>Centroptilum</i>	2	2	COL
<i>Baetis</i>	2	6	COL
<i>Boyeria</i>	1	2	PRE
<i>Calopteryx</i>	2	5	PRE
<i>Neohermes</i>	1	2	PRE
<i>Gammarus</i>	23	6	COL
<i>Caecidotea</i>	6	6	COL
<i>Crangonyx</i>	5	4	COL
OLIGOCHAETA	7	10	COL
<i>Pisidium</i>	16	5	FIL
<i>Pseudosuccinea</i>	1	6	COL
Total No. Individuals	211		

Abbreviations: FFG-functional feeding group, TV-tolerance value, SCR-scrappers, PRE -predators, SHR -shredders, FIL-filterers, COL-collectors.

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Table 4-2. Determining the biological integrity indicator for the waterbody*.

Note: Each of the seven metrics are calculated using raw data resulting from laboratory analysis. Metric values are normalized by comparison to scoring criteria, allowing them to be summed to a total index, or bioassessment, score. Comparing the total index score to narrative rating categories results in the a condition narrative .

Metric	Value	Score
TotTax	32	5
EPT Tax	10	5
%EPT	19.4	3
%Chir	37.4	3
TrichTax	6	5
HBI	5.2	5
%ColFil	12.3	1
Total Index Score		27

BIOLOGICAL INTEGRITY INDICATOR:
Good

* See previous box entitled "Metric Definitions." As noted in Section 4.1, other approaches to achieving biological assessment and habitat levels 3 or 4 (Tables 3-1 and 3-2) can be used to

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determine the biological integrity for a waterbody. See also example case studies for ALUS assessments in Section 3 for more information about assessment quality.